Safety and Feasibility of an Exercise Prescription Approach to Rehabilitation Across the Continuum of Care for Survivors of Critical Illness

Sue Berney, Kimberley Haines, Elizabeth H. Skinner, Linda Denehy

Background. Survivors of critical illness can experience long-standing functional limitations that negatively affect their health-related quality of life. To date, no model of rehabilitation has demonstrated sustained improvements in physical function for survivors of critical illness beyond hospital discharge.

Objective. The aims of this study were: (1) to describe a model of rehabilitation for survivors of critical illness, (2) to compare the model to local standard care, and (3) to report the safety and feasibility of the program.

Design. This was a cohort study.

Methods. As part of a larger randomized controlled trial, 74 participants were randomly assigned, 5 days following admission to the intensive care unit (ICU), to a protocolized rehabilitation program that commenced in the ICU and continued on the acute care ward and for a further 8 weeks following hospital discharge as an outpatient program. Exercise training was prescribed based on quantitative outcome measures to achieve a physiological training response.

Results. During acute hospitalization, 60% of exercise sessions were able to be delivered. The most frequently occurring barriers to exercise were patient safety and patient refusal due to fatigue. Point prevalence data showed patients were mobilized more often and for longer periods compared with standard care. Outpatient classes were poorly attended, with only 41% of the patients completing more than 70% of outpatient classes. No adverse events occurred.

Limitations. Limitations included patient heterogeneity and delayed commencement of exercise in the ICU due to issues of consent and recruitment.

Conclusions. Exercise training that commences in the ICU and continues through to an outpatient program is safe and feasible for survivors of critical illness. Models of care that maximize patient participation across the continuum of care warrant further investigation.
There is increasing interest in the provision of rehabilitation for survivors of critical illness as a result of improved survival rates and reports of long-standing functional limitation that negatively affects their health-related quality of life. A critical care admission, particularly for prolonged periods, can result in the development of clinically significant weakness that has been reported to last up to 5 years following hospital discharge. Physical limitations that survivors of intensive care experience have been well documented. In particular, patients who require more than 48 hours of mechanical ventilation or who have sepsis are at high risk for the development of significant muscle weakness in the intensive care unit (ICU). Intensive care unit–acquired weakness has both short-term and long-term consequences for the patient, including delayed weaning from mechanical ventilation, reduced functional capacity, and inability to return to work. For older patients, this decline in physical function and ability to complete activities of daily living is even more pronounced.

Several models of rehabilitation for critical illness have been proposed, based on established programs such as stroke and pulmonary rehabilitation. To date, these models have concentrated on early mobilization and rehabilitation commenced in the ICU and continued on the acute care ward. Although these models have shown improved short-term functional outcomes at hospital discharge and potentially lower hospital readmission rates, no research has used a protocolized exercise intervention aimed at achieving a physiological response or investigated the effects on physical function at 12 months following ICU discharge.

The aims of this study were: (1) to report the components of an exercise rehabilitation program for survivors of critical illness that commenced in the ICU and continued for 8 weeks following hospital discharge, (2) to compare the program with local and national standard care and with other models of rehabilitation that have been reported in international literature, and (3) to report the safety and feasibility of providing exercise training for patients who survive critical illness.

**Method**

**Design**

The current study was a single arm of a larger, parallel group randomized controlled trial. Seventy-four participants were randomly assigned to a protocolized rehabilitation program that commenced in the ICU and continued on the acute care ward and for a further 8 weeks following acute care facility discharge as an outpatient program.

**Participants**

Study participants were recruited from a metropolitan tertiary 20-bed ICU in Melbourne, Australia, between May 2007 and August 2009. Participants were included if they were older than 18 years of age, were admitted to the ICU for 5 or more days, were able to understand written and spoken English, and resided within a 31.25-mile (50-km) radius of the hospital. Participants were excluded if they had a major disorder of the central nervous system that resulted in permanent weakness, had conditions that rendered participation hazardous (eg, long-bone or unstable fractures), were assessed by senior medical staff as approaching imminent death or withdrawal of medical treatment in the ensuing 48 hours, had a length of stay greater than 5 days due to non-availability of an acute care bed, or had a premorbid condition resulting in not being able to perform the outcome measures. Written informed consent was obtained from participants or, if they were unable to provide informed consent, their designated decision maker.

**Procedure**

Participants were screened for suitability for inclusion 5 days after admission to the ICU. They were randomized using opaque envelopes in a 1:1 manner to an exercise training rehabilitation program in addition to standard care or to standard care alone. Standard care referred to medical, nursing, and physical therapy management. The staffing structure and model of care provided in the ICU in Australia has been described elsewhere. Physical therapy standard care included respiratory assessment and treatment as required and early mobilization. Only data for participants who received exercise training rehabilitation in addition to standard care are analyzed in this article. The flow of participants through the intervention arm of the study is presented in Figure 1.

Baseline measurement of physical function was performed using the Physical Function in ICU Test (PFIT). The PFIT is a submaximal exercise test that was developed for patients in the ICU who may not be able to mobilize away from the bedside. The original test had 4 domains and 5 components and has been shown to be both reliable and sensitive to change. The test requires the patient to march in place for as long as he or she is able and to move from a sitting to a standing position while the therapist measures the amount of physical assistance required; the
therapist measures knee extension and shoulder flexion muscle strength using the Oxford Scale and records the number of shoulder flexion repetitions. A walker with wheels was placed in front of the patient to use as required during the march in place and any subsequent mobilization. The level of assistance to stand was reassessed daily, prior to marching, and the use of a walker was recorded. This test has been described in detail elsewhere. The intensity of exercise was prescribed based on the results of the test. The time spent marching in place was used to assess gait endurance; for exercise training, participants were instructed to march in place for 70% of the time that they had achieved in their baseline test, in accordance with the guidelines for exercise training published by the American College of Sports Medicine.

Participants who were considered safe to exercise according to predefined criteria commenced a hierarchical, standardized protocol that included endurance, functional, and strength training. If participants were unable to sit out of bed, assisted active exercises were performed in bed. Exercise training was provided for 15 minutes twice daily, 6 days per week. Once the patient was discharged from the ICU, exercise training was provided 30 minutes twice daily, until the patient could perform exercise for 1 hour, 6 days per week. Training was conducted either on the acute care ward or in a gym located elsewhere in the hospital. An outpatient exercise program was commenced within 2 weeks of hospital discharge. Exercise classes were provided for 1 hour twice a week for 8 weeks. If participants were required as part of standard care to attend other outpatient classes (eg, cardiac and pulmonary rehabilitation), these classes were deferred until the 8-week exercise program was completed. Participants received any home-based physical therapy services that the ward physical therapist deemed appropriate. Participants were provided with taxi vouchers or were reimbursed for parking fees.

**Exercise Rehabilitation Intervention**

Exercise training in the ICU included marching in place or walking away from the bed, repetitive sit-to-stand practice, arm and leg strengthening, and active bed exercises (Tab. 1). The hierarchical program required that participants first perform 3 timed sets of marching in place or walking; if 15 minutes of training was not achieved, it was followed by moving from a sitting to a standing position until the patient could no longer perform the task with the same level of assistance and upper-limb strength training until a total of 15 minutes of exercise was
achieved. We aimed to exercise participants to a rating of perceived exertion (RPE) of 3 to 5 on the modified Borg Scale, and marching time was progressed by increasing the time by 10% each session, provided the RPE was no greater than 4 on the previous session. Weaning the patient from mechanical ventilation was done in accordance with the weaning protocol of the ICU. Administration of intravenous sedation in the ICU was titrated to achieve a Richmond Agitation and Sedation Scale score between to 1.20

The safety of the ICU training protocol was assessed by the occurrence of adverse events during training and the ensuing 30 minutes. The RPE, via the modified Borg Scale, oxygen saturation, heart rate, and mean arterial blood pressure were monitored during testing and training. These physiological measures were chosen because they have previously been reported as those most commonly monitored by physical therapists in the ICU in Australia.17

Once patients were discharged from the ICU, the intensity of exercise training was prescribed according to either the ICU discharge PFIT or, when the participants could mobilize 10 m, the Six-Minute Walk Test (6MWT). Once discharged from the hospital, patients commenced an outpatient exercise program. Participants were required to attend twice per week for 8 weeks. Exercise was prescribed using the results of a stationary cycle submaximal oxygen consumption test that was performed according to a standardized protocol for patients with chronic heart failure.21 The aim of the test was to exercise participants to just beyond 85% of predicted maximum heart rate or to an RPE of 7 on the Borg Scale. The work of cycling increased incrementally each min-

Table 1. Intensive Care Unit (ICU) Exercise Trial Intervention

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICU</th>
<th>Ward</th>
<th>Outpatients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of cardiovascular exercise</td>
<td>Marching in place</td>
<td>Walking (on ward/treadmill)</td>
<td>Walking (treadmill)</td>
</tr>
<tr>
<td>Walking away from the bedside</td>
<td>Bike</td>
<td>Bike</td>
<td></td>
</tr>
<tr>
<td>Intensity of cardiovascular exercise</td>
<td>Target RPE 3–5</td>
<td>Interval training for endurance RPE 4–5 or, if appropriate, 60%–70% of maximum heart rate (220 – age) At &gt;2 wk after ICU discharge, increase RPE 5–6</td>
<td>Progression to longer work interval training for endurance RPE 5–6 or 80% of maximum heart rate</td>
</tr>
<tr>
<td>Duration of cardiovascular exercise</td>
<td>3 repetitions of 70% of initial PFIT marching in place time, including rests</td>
<td>10–15 min</td>
<td>30 min</td>
</tr>
<tr>
<td>Intensity of strength training</td>
<td>Until fatigue</td>
<td>75% of SRM</td>
<td>75% of SRM</td>
</tr>
<tr>
<td>Type of strength training</td>
<td>&gt;Grade 3 strength, active to resisted</td>
<td>Resisted upper limb, trunk, pelvis, lower limb (dumbbells, Thera-Band [The Hygenic Corporation, Akron, Ohio], own body weight)</td>
<td>Resisted upper limb, trunk, pelvis, lower limb (dumbbells, Thera-Band, own body weight)</td>
</tr>
<tr>
<td>Repetitions for strength training</td>
<td>Start 5 repetitions each limb Progress to 3 sets of 10 repetitions as able</td>
<td>1–2 sets, 12–15 repetitions</td>
<td>1–2 sets, 12–15 repetitions</td>
</tr>
<tr>
<td>Functional retraining</td>
<td>Sit-to-stand (using tilt table or standing walker if unable), rolling, supine to sitting, trunk control/balance</td>
<td>Sit-to-stand, rolling, supine to sitting, trunk control/balance Stairs</td>
<td>Sit-to-stand (body weight or loaded), rolling, supine to sitting, trunk control/balance Stairs</td>
</tr>
<tr>
<td>Total session time composition</td>
<td>15 min to complete: —March in place time OR —March in place + strength OR —March in place + strength + functional retraining OR —Whole-body bed exercises</td>
<td>30 min to complete: —Cardiovascular, 10–15 min —Strength, 10 min —Functional retraining, 5–10 min</td>
<td>60 min to complete: —Cardiovascular, 30 min —Strength, 20 min —Functional retraining, 10 min</td>
</tr>
<tr>
<td>Frequency of sessions</td>
<td>2×15 min/day Aim for 1×30 min/day</td>
<td>2×30 min/day Aim for 1×60 min/day</td>
<td>1×60 min/2×week</td>
</tr>
</tbody>
</table>

* RPE—rating of perceived exertion as measured using the modified Borg Scale, PFIT—Physical Function in ICU Test, RM—repetition maximum.
* If patient was unable to stand or march in place, commenced focused strength and functional retraining.

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ute, and a metronome was used to maintain cadence. Heart rate and oxygen saturation were monitored each minute throughout the test via pulse oximetry, and blood pressure and heart rate were recorded prior to the test and every 2 minutes following the test, until the participant reported an RPE of 3 and the heart rate was reduced by 20 bpm. If participants had been prescribed beta-blockers, the test was not performed. The test was ceased if participants complained of chest pain, dizziness, or severe shortness of breath. If participants were unable to perform the bike test, the 6MWT was used for exercise prescription. Participants were considered to have attended the program if they were present at 70% or more of the classes. Participants were encouraged to complete a walking program on the days they did not attend outpatient classes; instructions for intensity and safety were provided.

Rehabilitation programs, both in the acute care ward and outpatient setting, were individualized for each patient; however, where possible, programs were administered in a group setting by the trial physical therapist in consultation with an exercise physiologist on the acute care ward and in the outpatient clinic. An example of an individualized exercise program is presented in Appendix 1.

To measure standard care, point prevalence data were collected in the ICU on 10 occasions. On the designated point prevalence day, data from the previous 24 hours describing all physical therapy management, including rehabilitation and mobilization practices, were collected on all patients in the ICU who required mechanical ventilation for longer than 48 hours. The day of the month and time of data collection were randomly allocated. Acute care ward point prevalence data describing rehabilitation and mobilization practices were collected for control participants 131 to 150.

Safety Procedures
Several strategies were used to maximize safety during exercise training and prevent adverse events. All physical therapists working in the trial were required to have more than 2 years of clinical experience in the ICU. Written manuals of protocols and safety guidelines were supplied to all research personnel. Criteria to determine when exercise training was unsafe to commence or whether exercise training should be ceased were developed by the investigators in conjunction with senior medical staff in the ICU (Appendix 2). If any adverse event occurred, either during or in the ensuing hour following intervention or outcome measurement, the chief investigators were notified. Research personnel met weekly to discuss trial progress and process indicators, based on the trial consort diagram, and were reviewed monthly to identify any potential safety, recruitment, or treatment issues. A data monitoring committee examined trial safety by reviewing adverse events every 6 months. Serious adverse events were defined a priori (Appendix 3). Any serious adverse event that occurred in the course of treatment, during measurement, or in the ensuing hour was reported to both the chief investigators and the Human Research and Ethics Committee.

Apart from the presence of an intra-aortic balloon pump or femoral access device for extra corporeal membrane oxygenation, exercise was not precluded by the presence of invasive lines, consistent with unit protocol. If a patient required continuous renal replacement therapy and had a femoral access device in situ, he or she could sit out of bed but not mobilize and performed upper-limb strengthening exercises as per the protocol. Nasogastric feeds were not ceased during exercise training.

Data Collection
Prior to the commencement of exercise in the ICU, we recorded wakefulness, assessed by the ability to follow 3 commands: the presence of mechanical ventilation, weaning, and airway status. Prior to and following exercise, the following parameters were recorded: heart rate, respiratory rate, oxygen saturation via pulse oximetry, and RPE according to the modified Borg Scale. All data were collected on a standardized case report form. If a patient could not exercise, the reasons why the protocol could not be delivered were recorded. A session was considered to be complete if more than 10 minutes of exercise was achieved; if less than 10 minutes of exercise was performed, the session was considered incomplete. However, if exercise was unable to commence, it was recorded as undeivered. If a participant was readmitted to the ICU, the PFIT was reassessed and exercise delivered according to the ICU protocol.

On the acute care ward, heart rate, blood pressure, respiratory rate, and temperature were assessed from the nursing observation chart and were recorded if exercise was unable to be commenced in accordance with the safety parameters. Prior to and upon completion of an exercise session, heart rate and blood pressure were measured; RPE was recorded during aerobic exercise and trial testing. Pulse oximetry was used when participants required supplemental oxygen to exercise. An exercise intervention on the acute care ward was recorded as complete if the
Table 2.
Demographic and Outcome Data of the Intervention Group and the Intensive Care Unit (ICU) Point Prevalence Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICU Exercise Trial Intervention Group (n=74)</th>
<th>ICU Point Prevalence Group (n=68)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y), X (SD)</td>
<td>61.4 (15.9)</td>
<td>62 (11.1)</td>
</tr>
<tr>
<td>Sex (% male)</td>
<td>68.4</td>
<td>72.3</td>
</tr>
<tr>
<td>BMI (kg/m²), X (SD)</td>
<td>27.5 (5.4)</td>
<td></td>
</tr>
<tr>
<td>APACHE II, X (SD)</td>
<td>19 (6)</td>
<td></td>
</tr>
<tr>
<td>Ventilated at day 5, n (%)</td>
<td>41 (55%)</td>
<td>41 (60%)</td>
</tr>
<tr>
<td>ICU LOS, median (IQR)</td>
<td>8 (6–11)</td>
<td>7 (4–13)</td>
</tr>
<tr>
<td>Acute LOS, median (IQR)</td>
<td>24 (16–42)</td>
<td></td>
</tr>
<tr>
<td>ICUAW (% yes)</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>MV (hr), median (IQR)</td>
<td>105 (52–216)</td>
<td></td>
</tr>
<tr>
<td>28-day mortality (%)</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>Incidence of tracheostomy (%)</td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>Time to tracheostomy, X (SD)</td>
<td>8.4 (3)</td>
<td></td>
</tr>
<tr>
<td>Time from admission to first exercise session (d), median (IQR)</td>
<td>7 (5–11)</td>
<td></td>
</tr>
<tr>
<td>Functionally independent at hospital discharge (%)</td>
<td>59.5</td>
<td></td>
</tr>
<tr>
<td>Required inpatient rehabilitation, n (%)</td>
<td>15 (20%)</td>
<td></td>
</tr>
</tbody>
</table>

*BMI=body mass index, APACHE II=Acute Physiology and Chronic Health Evaluation score, LOS=length of stay, IQR=interquartile range, ICUAW=ICU-acquired weakness (Medical Research Council sum score <48), MV=mechanical ventilation.

A patient was able to achieve more than 20 minutes and incomplete if less than 20 minutes was achieved. If the exercise protocol was not able to commence, it was recorded as undelivered. An incomplete session in the outpatient exercise class was classified as completing less than 30 minutes of training.

Outcome Measurement

All outcomes were measured by a physical therapist blinded to group allocation. The PFIT was measured in the ICU at baseline on recruitment, once weaned from mechanical ventilation, and at ICU discharge. The 6MWT was performed following ICU discharge to the acute care ward once the patient was able to mobilize more than 10 m unassisted and at hospital discharge. Two tests were performed at each time point in accordance with American Thoracic Society guidelines. The greatest distance walked in 6 minutes was recorded, and treadmill exercise was prescribed at 80% of the calculated speed achieved in the test, consistent with recommendations of the Australian Lung Foundation. A submaximal oxygen consumption test on a bicycle was performed at the commencement of the outpatient program, and two 6MWTs were performed on completion of the training program. As part of the larger trial, participants were followed up at 6 and 12 months following ICU discharge.

Data Management

Descriptive statistics were predominantly used to analyze data using PASW Statistics version 18 (SPSS Inc, Chicago, Illinois). Data are presented as percentages, mean (standard deviation), or median (interquartile range). Data are analyzed for all available treatment sessions throughout the trial.

Role of the Funding Source

The larger trial received funding support from the National Health and Medical Research Council of Australia, the Australian New Zealand College of Anaesthetics, the Physiotherapy Research Foundation, and the Austin Health Medical Research Foundation.

Results

From May 2007 to August 2009, 74 participants underwent the protocolized exercise rehabilitation program. Demographic data and outcomes are presented in Table 2. The participants were broadly representative of the 83,000 participants admitted to the ICU in public hospitals in Australia each year. A total of 2,190 potential exercise sessions were available during the acute hospitalization phase, of which 1,309 were delivered. Of these 1,309 exercise sessions, 72 (6%) were classified as incomplete (Fig. 2).

In the ICU, a total of 1,168 potential exercise sessions were available. Of these, 641 (55%) were delivered and 611 (95%) were complete. The reasons for incomplete sessions were participants reaching exercise-cessing criteria or fatigue. On 527 occasions (45%), exercise rehabilitation could not be delivered. The most common reasons for failure to deliver exercise sessions both in the ICU and on the acute care ward are presented in Table 3. The most frequent reason for participant refusal to exercise in the ICU (80 occasions [53%]) and on the ward (87 occasions [52%]) was fatigue.

Following discharge to the acute care ward, 81% of the participants were able to perform the 6MWT. On the acute care ward, a potential 1,022 sessions were available, of which, 668 (65%) were delivered and 42 (6%) were classified as incomplete. Three hundred fifty-four exercise sessions were not able to be delivered (Fig. 2).
No adverse event occurred during exercise training either in the ICU or on the acute care ward. Two events, classified as serious adverse events, were detected prior to the commencement of exercise training by the intervention physical therapist (1 participant was unable to be awakened and subsequently found to have a bleeding duodenal ulcer, and 1 participant had an oxygen saturation level less than 85%, as measured by pulse oximetry). Although trial participants were not undergoing intervention at the time, medical emergency calls were placed by the intervention physical therapist. These events were reported to the Human Research Ethics Committee.

Prior to commencement of the outpatient exercise program, 10 participants died and 3 withdrew from the program, leaving a total of 61 participants. Therefore, a potential 976 exercise sessions were available. Of these, 455 (47%) exercise sessions were attended. All exercise sessions were completed. Of the 61 participants, 42 attended their first exercise session. Of the 42 attendees, 29 (69%) were able to perform a submaximal exercise test on the bicycle. In total, 25 of the 61 participants (41%) were considered to have attended the outpatients rehabilitation program, with 12 of these 25 participants (48%) attending 100% of classes (Fig. 3).

In the ICU, on 76% of occasions, participants were able to adhere to the protocol requirement to march in place or mobilize away from the bedside. Point prevalence data of a similar cohort indicated that 52% of patients receiving standard care in the same ICU were mobilized. Demographic data of these 68 patients are presented in Table 2. On the acute care ward, on 6% of occasions, participants were unable to complete 60 minutes of exercise per day. Point prevalence data of participants in the standard care group (n=20) indicated that ward participants performed an average of 22 minutes of mobility and rehabilitation per day at the same institution.

**Discussion**

The results of this study suggest that exercise rehabilitation as described, using strict safety criteria, is safe and feasible for patients who are critically ill and throughout the recovery period. The rehabilitation approach used in this study was based on exercise prescription using quantitative tests, such as the 6MWT or the PFIT.
to achieve a physiological training response. According to point prevalence data, this approach resulted in higher rates of mobility in the ICU and longer duration of exercise training in the acute care ward compared with standard care. Recent point prevalence data for mobilization practices in 43 Australian and New Zealand ICUs demonstrated only 13% of the 393 patients were mobilized in a cohort admitted for longer than 48 hours. The cohort included patients who were mechanically ventilated and spontaneously breathing. These data were collected on a designated day and reflected the mobilization practices of the previous 24 hours of the patient stay (unpublished data). The point prevalence data from our study suggest that the intervention group received substantially greater mobilization than standard care, highlighting the benefits of a quantitative approach to exercise training. However, the mobilization practices in the group receiving standard care highlight the culture of early mobility that already existed in the ICU.

Despite the training approach used in the current study, no adverse events occurred, and there was neither inadvertent removal of invasive devices nor disconnection from ventilatory support. Participants ceased exercise on less than 5% of occasions during acute hospitalization. This finding is consistent with the findings of other investigators who also reported low incidence of adverse events.\textsuperscript{11,13,27} The safety criteria used in this study were broadly consistent with those reported previously.\textsuperscript{11–13} However, in contrast to other studies,\textsuperscript{12,13} both the current study and that of Burtin and colleagues\textsuperscript{11} used a ceiling pressor dosage, above which exercise was not permitted. This pressor safety criterion may have influenced the inability of a larger number of participants to commence exercise in our study and the delay to initiate exercise observed in the study by Burtin and colleagues.\textsuperscript{11} Although differences in medical management may influence pressor usage, the low rate of adverse events observed in the trials of Morris et al\textsuperscript{12} and Schweickert and colleagues\textsuperscript{13} indicate that the pressor safety criterion used in this study was too restrictive and resulted in a high number of exercise sessions not being initiated and should be reconsidered in future trials.

Several other barriers to rehabilitation were observed in this study. On 491 occasions, patients refused to exercise (primarily due to fatigue) or were not available to exercise due to procedures being performed. Although the increased intensity of exercise training may have led to increased patient fatigue, the bed-based approach to the management of hospitalized patients, where the default is for patients to remain in bed, also may have influenced the high rates of fatigue and refusal to

### Table 3.

Occurrence of the Most Common Reasons for Failure to Deliver Exercise Sessions and Barriers to Exercise Training in Intensive Care Unit (ICU) and on the Ward

<table>
<thead>
<tr>
<th>Reason/Barrier</th>
<th>ICU</th>
<th>Ward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient refusal</td>
<td>152</td>
<td>168</td>
</tr>
<tr>
<td>Outside predefined cardiovascular and respiratory safety criteria</td>
<td>139</td>
<td>61</td>
</tr>
<tr>
<td>Not available due to procedure being performed</td>
<td>91</td>
<td>125</td>
</tr>
<tr>
<td>Sedated or encephalopathic</td>
<td>80</td>
<td>13</td>
</tr>
<tr>
<td>State of agitation</td>
<td>58</td>
<td></td>
</tr>
</tbody>
</table>

## Figure 3.

Outpatient exercise sessions achieved.
exercise observed in this study. Given the increasing understanding of the legacy of an ICU admission and the potentially important influence of early mobility and activity, we contend that rehabilitation should not be considered a discretionary aspect of care that can be slotted around other procedures, but procedures should instead be planned around the provision of rehabilitation.

The conscious state of the patient, particularly in the ICU, resulted in 80 sessions not being provided. However, on 50% of occasions impaired consciousness was due to an encephalopathic state and not related to sedation practices. Nonetheless, despite a sedation protocol, on 40 occasions, participants were not within the acceptable Richmond Agitation-Sedation Scale range.

Although the cohort in the current study was similar to that reported by Schweickert and colleagues in terms of illness severity, the differences in methods and medical management may have resulted in differences observed in the feasibility of exercise training in the ICU and the rates of exercise performed while on mechanical ventilation. In addition to the previously mentioned barriers to exercise, a major difference between our study and that of other investigators was the attempt to exercise patients twice daily. This attempt resulted in a greater risk that patients would not be available due to procedures and a greater opportunity for participants to refuse exercise training. However, when participants were available and could exercise safely, training occurred on 81% of occasions, which was consistent with previous reports of exercise in the ICU. Reducing the training regimen to once daily may potentially have improved adherence.

The main difference between this study and others was the approach to exercise rehabilitation. Schweickert et al and Morris et al targeted training of functional activities of daily living that progressed by meeting predefined milestones with repetition requirements. In contrast, we attempted to achieve a training effect of exercise that involved the patient performing highest level of activity possible and progressively reducing the difficulty of the task in a prescribed dosage and time interval. Further comparison of the results of the current study with those of the study by Burtin et al is limited due to methodological and clinical differences. Their cohort had a higher illness severity, longer length of the ICU and hospital stay, and dealt differently with ongoing cardiovascular and respiratory compromise following inclusion, making comparison of feasibility of exercise training difficult to interpret. In addition, exercise rehabilitation was provided in the ICU only, and the delay prior to inclusion and commencement of the intervention was 14 (10) days, which was greater than our median ICU length of stay.

This study, as part of a larger prospective randomized controlled trial, is the first to provide exercise training across the continuum of critical illness. Although other trials have provided rehabilitation in the ICU and on the acute care ward, this study additionally provided transition training back into the community, based broadly on the approach of a pulmonary rehabilitation program. There was, however, a delay in the commencement of exercise training in the ICU due to issues of recruitment and consent. Exercise training could have been further optimized if we had asked senior medical staff to predict, at 48 hours following admission, which patients were likely to require 5 or more days in the ICU. This approach would have facilitated earlier screening and recruitment and resulted in increased levels of exercise training in the ICU. Other investigators have previously reported that patients who received rehabilitation in the ICU experienced less delirium. However, no comparison can be made with the current study as measurement of delirium was not routinely performed at our institution.

The outpatient component of the rehabilitation program was poorly attended. Despite the provision of taxi vouchers, patients frequently mentioned travel distance and limited time as reasons for not attending sessions. Other participants felt there was no requirement for ongoing exercise training and rehabilitation. It also was possible that participants with poor social support and potentially the poorest quality of life were those that failed to attend. The low attendance at the hospital-based outpatient program suggests that alternative models of care, such as home- or community-based rehabilitation programs or self-efficacy training, are needed to engage patients to produce sustained changes in exercise behavior. This study also was limited by patient heterogeneity, as evidenced by almost half of the patients not being ventilated at the time of recruitment. However, when this study was conceived, little was understood about who would respond, who was safe to exercise, or who was at high risk for the development of muscle weakness in the ICU. As a result, the pragmatic decision was made to include patients with a prolonged stay. Future studies may choose to define which populations to include (eg, patients with sepsis), to reduce variability.

Given the long-term functional impairment of survivors of critical illness, the results of the current study and others suggest that there is merit in providing ongoing rehabilitation that is continued following hospital discharge. However, models to deliver this reha-
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bilitation that are acceptable to patients and their families need future consideration. There is now convincing evidence that commencing exercise in the ICU is safe and feasible, and can be started earlier than in the current trial.13 Models of care that enhance exercise and activity while patients are on the acute care ward warrant investigation.

Given the substantial muscle loss that can occur in the first 7 days of an ICU admission, future research is needed into nonvolitional exercise rehabilitation that can start early in the ICU, even if the patient is sedated and unable to cooperate. In addition, long-term follow-up studies are needed to identify patients who are at risk of developing long-standing weakness in order to commence targeted programs of rehabilitation early in the course of critical illness.

In conclusion, protocolized exercise training that is prescribed using quantitative measures at each phase of critical illness recovery is safe and feasible for survivors of critical illness. A model that includes exercise started in the ICU and continuing in an outpatient program can produce sustained improvements in functional capacity.

References


Dr Berney and Dr Skinner provided concept/idea/research design. Dr Berney, Ms Haines, and Dr Deneyh provided writing. Ms Haines and Dr Skinner provided data collection. All authors provided data analysis. Ms Haines provided project management. Dr Berney and Dr Deneyh provided fund procurement. Dr Skinner provided institutional liaisons. Ms Haines, Dr Skinner, and Dr Deneyh provided consultation (including review of manuscript before submission).

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